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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAM

OF THE

CHICAGO MEETING

NOVEMBER 27–28, 1931

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COUNCIL

The council of the Society consists of the president, vice-president, secretary, treasurer and managing editor as given above, and all living past presidents and eight elected members as follows:

Past Presidents: Carl Barus, E. L. Nichols, Henry Crew, W. F. Magie, Ernest Merritt, R. A Millikan, J. S. Ames, Theodore Lyman, C. E. Mendenhall, D. C. Miller, K. T. Compton, and H. G. Gale.

Elected Members: L. J. Briggs, H. L. Bronson, H. E. Ives, A. L. Loomis, L. W. McKeehan, D. L. Webster, W. D. Coolidge, and F. W. Loomis.

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NOVEMBER 12, 1931 Vol. 6, No. 4

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CHICAGO MEETING, NOVEMBER 27–28, 1931

The 173rd regular meeting of the American Physical Society will be held in Chicago, Illinois, at the Ryerson Physical Laboratory of the University of Chicago on Friday and Saturday, November 27 and 28, 1931. The first sessions will be at 2 o'clock on Friday afternoon.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction, they will be published in an early number of the Physical Review. Authors should send corrections to the Editor of the Physical Review, University of Minnesota, Minneapolis, Minn.

Dinner. On Friday evening at 7 o'clock there will be a dinner for the members of the Society and their friends in the Banquet Room of the Hotel Windermere. The price per person will be $2.00. Tickets should be purchased in the Ryerson Physical Laboratory before 2 o'clock Friday afternoon. In case this is impossible it will be advisable to write in advance for reservations.

Luncheon. Luncheons may be secured at the University Coffee Shop or at the cafeteria in Hutchinson Hall.

Adler Planetarium. Members who wish to inspect the Adler Planetarium with explanatory lecture by Dr. Philip Fox, Director, are invited to be present on Saturday morning at 9:30 o'clock. The admission to this lecture and demonstration is twenty-five (25¢) cents.

Hotel Headquarters. The Hotel Windermere East, east of the Illinois Central Station on 56th Street, has been selected as hotel headquarters. A few single rooms in the hotel are available at $2.50. Double rooms are $2.50 each. All rooms with bath.

NOV 17 1931

CALENDAR

Friday morning at 10:30 o'clock	Room 316, Eckhart, Meeting of the Council
Friday afternoon at 2 o'clock	Room 133, Eckhart: Papers 1–11
Friday afternoon at 2 o'clock	Room 32, Ryerson: Papers 12–20
Friday evening at 7 o'clock	Dinner at the Hotel Windermere
Saturday morning at 10:30 o'clock	Room 32, Ryerson: Papers 21–27
Saturday morning at 10:30 o'clock	Room 133, Eckhart: Papers 28–34
Saturday afternoon at 2 o'clock	Room 32, Ryerson: Papers 35–41
Saturday afternoon at 2 o'clock	Room 133, Eckhart: Papers 42–50

The supplementary papers beginning with No. 51 may be called for at the end of any one of the sessions held in Room 133, Eckhart Hall.

New Orleans Meeting. The preliminary arrangements for the New Orleans program include joint sessions with the American Mathematical Society on Tuesday morning and afternoon with addresses by W. F. G. Swann, G. B. Birkhoff and G. A. Bliss including the Josiah Willard Gibbs Lecture by P. W. Bridgman. On Wednesday morning there will be a joint session with Section B of the A. A. A. S. with the address of the Retiring Vice-President of Section B. F. K. Richtmyer, and an address by H. H. Kimball. On Wednesday afternoon there will be a joint session with Section E of the A. A. A. S. and the Society of Petroleum Geophysicists for a geophysical program.

Headquarters. The Roosevelt Hotel, University Place near Canal Street, has been selected for hotel headquarters for the American Physical Society at New Orleans. Members are urged to make their reservations at once (writing directly to the hotel).

The rates at the Roosevelt are: single rooms, $4.00 to $6.00 per day; double rooms, $6.00 to $9.00 per day.

Members intending to present papers at this meeting should have the typewritten titles and abstracts (not exceeding 200 words) ready for publication, in the hands of the Secretary not later than Friday, November 20th.

Other meetings for the current season are as follows:

174. December 18–19, 1931. Pacific Coast. Berkeley.
175. Annual Meeting. New Orleans. December 29–30, 1931.
176. February 25–27, 1932. Cambridge.
177. April 28–30, 1932. Washington.
178. June 1932. Pacific Coast. Pullman, Washington.
179. June Meeting. New Haven. Time to be announced later.

W. L. SEVERINGHAUS, *Secretary*
Columbia University, New York, N. Y.

November 12, 1931.

PROGRAM

FRIDAY AFTERNOON AT 2 O'CLOCK

Room 133-Eckhart

1. X-ray diffraction of ethyl ether at the critical temperature. WALDEMAR NOLL, *University of Iowa.*—X-ray diffraction ionization curves were obtained for ethyl ether at 43.16 kg/cm² pressure with temperatures in the range from 25°C to 210°C. Liquid and gas types of curves were obtained. In the former case, there is a broad peak at 7.5° at 25°C with a decrease in the direction of both smaller and larger angles. In the gas type, the curve from a point near 0° falls rapidly with increasing angle but with the slope decreasing in magnitude. Immediately below the critical temperature is a combination of the two types, falling rapidly near 0°, then rising to a distinct peak and again falling with increasing angle. Because of the accentuation of general radiation by transmission through the aluminum vessel, the position of the peak is not that caused by ether alone, about 8.5° Mo$K\alpha$. If the height of peak be plotted with temperature, the curve has a course much similar to that of the latent heat of evaporation-temperature curve, decreasing more and more rapidly to the limiting value, zero, at the critical temperature. The experiments are in accord with the view of "cybotactic grouping" of the molecules occurring through the action of all the molecular forces including those which delineate the volume of a molecule.

2. X-ray diffraction with the two liquid phases of ethyl ether and nitrobenzene. G. W. STEWART, *University of Iowa.*—Wolfke and Mazur have found two liquid phases in ethyl ether and in nitrobenzene. The temperatures of transformation at atmospheric pressure are respectively −105.4°C and 9.5°C. The corresponding freezing points are −117.2°C and 5.7°C. The value of the latent heat of transformation for ethyl ether is 0.07 cal/gram and for nitrobenzene is unpublished. X-ray diffraction measurements, using Mo$K\alpha$ radiation, were made in the neighborhood of these transformation points with the result that distinctly rapid changes in the cybotactic groups were found for the ethyl ether and a noticeable change for the nitrobenzene. The x-ray diffraction measurements of liquids in general show a variation of "grouping" of the molecules with temperature. It becomes apparent that this variation may not always be continuous and when discontinuous may be accompanied by a latent heat of transformation. The statistical mechanism of the transformation is understood if explained in terms of the cybotactic groups.

3. A 600 kv x-ray plant. F. K. RICHTMYER, H. A. BARTON, AND M. T. JONES, *Cornell University.*—A 600 kv, two-section x-ray tube with an induction coil voltage source has been described in the General Electric Review by Dr. W. D. Coolidge. This tube has been loaned to Cornell University. The installation is in a separate building so situated that no lead housing for the tube is necessary. The walls of the building are of thick stone. Rays going through windows and roof will pass above all other structures. The distance to the latter is such that inverse square law provides ample protection from scattered rays. The door of the building is in the shadow of a lead house—to protect operator and instruments—of which the exposed wall is ½ inch thick while sides, back and roof are ⅜ inch thiick. All operations are carried out from the operator's house by remote control of a special power switchboard. Visual operation is provided by a periscope arrangement. Door switches, water switches, interlocking control relays, and other safety devices provide against accidents to persons or plant. The size of the focal spot is varied by means of a magnetic focusing coil and may be made as small as one centimeter diameter for a tube voltage of 500 kv.

4. Comparison of 700,000-volt x-rays and gamma-rays. G. FAILLA, *Memorial Hospital, New York.*—The cascade x-ray tube developed by Dr. Coolidge, of the General Electric Company, has been in operation at the Memorial Hospital since June. The tube is designed for a maximum voltage of 900,000 volts, and has been run at 850,000 volts for short intervals. It can be operated conservatively and for long periods of time at 700,000 volts and 5 milliamperes. The radiation output of the tube has been determined both as to intensity and quality, at different voltages. At 700,000 volts and 5 milliamperes the radiation emission, through a filter of

5 mm of copper, is equivalent to the gamma-ray emission of 400 to 600 grams of radium, depending on the criterion of equivalence chosen. This radiation can be measured by ionization after passing through 4 cm of lead. With the tube running several hours a day, the question of protection of personnel assumes great importance. The protective means employed will be illustrated. Absorption curves for different materials will be shown. These were determined under comparable conditions for x-rays at 200,000 to 725,000 volts and gamma-rays of radium.

5. Discrepancies in M series absorption edges of heavy elements. CHARLES WHITMER, *Olivet College.*—The M_3, M_4, and M_5 absorption edges have been measured for tantalum. The theoretical positions of these edges as computed from the L_3 edge differ by 2.9 units (in terms of ν/R) for the M_4 and M_5 edges; the discrepancy for M_3 in within the experimental error. The M_1, and M_2 edges could not be measured. These results agree with other results obtained at Iowa and at Upsala, showing quite generally among the heavier elements discrepancies of several units for the M_4 and M_5 edges and comparatively small ones for the M_1, M_2 and M_3 edges. Siegbahn explains these discrepancies as due to line absorption by M_2 and M_3 electrons involving transitions to the $O_{4,5}$ levels which are known to be unfilled for the elements below gold. The explanation probably does lie in line absorption but the particular transitions postulated by Siegbahn scarcely account for the results. The M_5 level more nearly represents true ionization than does the L_3 and may well be used as a reference level.

6. Peripheral x-ray levels of the heavy elements. J. A. ELDRIDGE, *University of Iowa.*—The discrepancies found in x-ray absorption levels are accounted for if it is assumed that electrons can only be displaced in absorption from the $M_{4,5}$ levels to levels in the energy diagram above the Sommerfeld free electron layer but from levels of smaller eccentricity transitions to other lower postulated levels are permitted. Such results throw much light upon the arrangement of the outer electrons in the elements of high atomic number. For the heaviest elements, thorium and uranium the transitions are all within the free gas layer and the discrepancies consequently smaller.

7. Variation in the effective lattice constant of crystals with wave-length. J. M. CORK, *University of Michigan.*—This investigation is carried out in order to determine if x-ray wave-lengths as recorded, based upon angular measurements with a calcite crystal, possess an appreciable error with wave-length due to a variation in the refractive index of the crystal. To this end the reflection angles for particular emission wave-lengths up to 5.5A are observed using a quartz crystal. These angles are combined with the recorded measurements of these same wave-lengths obtained with a calcite crystal. The value for log $[\lambda_{\text{calcite}}/2 \text{ Sin } \theta_{\text{quartz}}]$ when plotted with wave-length yields a curve with a discontinuity at a wave-length corresponding to the K absorption edge of calcium. It is shown that the shift in value of this ratio at the absorption edge is in the opposite sense to what would be expected from the generally accepted theory of refraction. A similar conclusion follows regarding the results of Siegbahn and Hjalmar in comparing calcite and gypsum. The dispersion theories of Kallmann and Mark and Kronig account satisfactorily for the discontinuity as observed.

8. The thermal motions of atoms in crystals. B. D. HOLBROOK, *University of Chicago.* (*Introduced by A. H. Compton.*)—The theory of the effect upon reflection of x-rays by crystals of the thermal motions of the atoms is reexamined, and an expression obtained for the distribution of the atom-centers about their mean positions; this expression involves only quantities directly obtainable from measurements (1) of the reflecting power of crystals for x-rays, (2) of the scattering of x-rays by gases. The distribution function is evaluated for a particular case, using for (1) data on the reflecting power of KCl at two temperatures, and for (2) data on the scattering of x-rays from argon; the results show that the atoms possess considerably more translational energy than is predicted by the classical theory, thus indicating the presence of zero-point energy.

9. The distribution of x-ray reflecting power in quartz crystals. CHARLES S. BARRETT AND CARL E. HOWE, *Naval Research Laboratory, Washington, D. C.*—In the study of the phenomena recently observed by Fox and Carr in piezoelectric quartz oscillators, Nishikawa, Sakisaka and Sumoto and independently ourselves, observed that non-oscillating crystals yielded Laue spots

that were doublets, oscillating crystals yielded solid spots. This indicated increased reflecting power of the entire crystal due to a reduced extinction of x-rays in the crystal lattice during oscillation. Further photographs with improved conditions indicate that in general Laue spots from oscillating crystals have a fine structure. The nature of the fine structure is such as to indicate that the increase of reflecting power of a given plane varies greatly from point to point in the crystal. At a given locality in the crystal the reflecting power of different planes is increased in different amounts with a resultant intensity distribution unlike that obtained from ground surfaces, but resembling that obtained from a non-oscillating crystal under elastic inhomogeneous strain. The intensity distribution from ground surfaces is explicable as the result of randomly directed strains in the surface. It may therefore be possible, with observations such as these (or similar ones taken stroboscopically), to analyze the distortions throughout the interior of quartz oscillators and resonators and other inhomogeneously strained crystals of suitable perfection.

10. Diffuse scattering of x-rays from sylvine at low temperature. G. E. M. JAUNCEY AND G. G. HARVEY, *Washington University, St. Louis, Mo.*—With a modification of the photographic method described by Claus the authors have compared the intensities of x-rays of wave-length 0.43A diffusely scattered from sylvine at angles in the range 25° to 90° at a temperature of 90°K with the intensities at these same angles at a temperature of 300°K. Jauncey and Harvey have shown that the intensity of the diffusely scattered rays should be given by

$$S = S' - F^2/Z,$$

where S' is independent of the temperature and F is the atomic structure factor containing the effect of thermal agitation. By using James and Brindley's F values at 90°K and 300°K theoretical values of S at 90°K have been calculated. The experimental values of S at 90°K are lower than the theoretical values. This result is in accord with that found by Claus for rocksalt. Plotting log $(S'-S_1)/(S'-S_2)$, where the subscripts refer to the two temperatures, against $(\sin^2 \phi/2)/\lambda^2$ a straight line is obtained whose slope agrees with that required by the Waller and not the Debye formula for the temperature effect. It is impossible by means of this experiment to show whether or not there is zero point energy. In order to do this an assumption concerning the electron distribution in the atom must be made.

11. Absorption of soft x-rays in air, oxygen, and argon. R. G. SPENCER, *The University of Chicago. (Introduced by Elmer Dershem.)*—A crystal spectrograph of high resolving power for measuring absorption coefficients of soft x-rays in gases has been constructed. Absorption measurements have been made for air, oxygen, and argon for four spectral lines of wave-lengths 1.537, 2.284, 4.145, and 6.973A. By using general radiation, absorption coefficients have been measured in the regions immediately adjacent to the K absorption limit of argon within 0.002A of the limit on each side of it. No departure from the ordinary absorption law greater than experimental error was found in these regions. The magnitude of the K absorption discontinuity of argon has been measured by a method which does not depend upon the extrapolation of curves to the limit. The following table gives the absorption coefficients obtained for both spectral lines and general radiation.

	1.537A	2.284A	3.716A	3.8637A	3.8677A	3.946A	4.145A	6.973A
Air	9.54	29.3					168.	747.
Oxygen	11.6	35.5					22.1	971.
Argon	112.	344.	1320.	1465.	147.	151.	171.	762.

FRIDAY AFTERNOON AT 2 O'CLOCK

Room 32-Ryerson

12. The effect of temperature on the absorption bands of benzene and some of its derivatives at low temperatures. A. H. CROUP, *University of Pittsburgh.*—The ultraviolet absorption spectra of benzene and the derivatives, ortho, meta, and para dichlorbenzene, were investigated throughout the temperature range from −190°C to 20°C. The behavior of the

spectra of the four compounds is very similar. They all show a number of unresolved major and minor absorption bands. Both the frequency and the intensity of these bands increase with a decrease of temperature. The temperature-frequency curves are all approximately represented by parabolic equations, except in the neighborhood of their melting points. The frequency difference between the bands remain constant with temperature within the limits of the experiment and agree favorably with those found by other spectroscopic methods. If these frequency differences are due to the vibrational transitions within the molecule, this spectral shift due to temperature cannot be accounted for on the basis of a change in the inner vibrational terms, as has previously been suggested. A preliminary theoretical discussion based on a recent paper of Pauling, shows that this shift may be due partly to a perturbed rotational motion of the molecule.

13. Band spectrum of potassium hydride. G. M. ALMY AND C. D. HAUSE, *University of Illinois.*—The band spectrum of potassium hydride has been photographed with a glass-prism, E−1 Hilger spectrograph. The source was a 220-volt d.c. arc in hydrogen at a pressure of a few mm of mercury. The spectrum obtained extends from 4100A to 5100A and is similar to the $^1\Sigma \rightarrow {}^1\Sigma$ systems of LiH and NaH. A short-exposure plate on which the spectrum extends from 4300A to 4900A has been analyzed. The spectrum consists of nine overlapping bands belonging to a single v' progression. The assignment of vibrational quantum numbers cannot be made from the present data. ω_x (where x is simply the number of the band and differs by a constant integer from the true $v'+\frac{1}{2}$) follows the relation:

$$\omega_x = 285.63 + 3.72x - 0.388x^2 - 0.0295x^3 + 0.0035x^4$$

ω_x rises to a maximum (as in LiH and NaH) before falling off in the conventional manner. The rotational analysis shows, (1) that the bands consist of P and R branches only so that the system is doubtless due to a $^1\Sigma \rightarrow {}^1\Sigma$ transition, (2) a great difference in the values of B and equilibrium distance (r_e) for the upper and lower states. The constants obtained are:

$B_x' = 1.432 - 0.001x^2$	$B'' = 3.379$
$D' = -1.44 \times 10^{-4}$	$D'' = -1.7 \times 10^{-4}$
$F' = 4.0 \times 10^{-8}$	$F'' = 1.4 \times 10^{-8}$
$r_e' \leqq 3.47 \times 10^{-8}$ cm	$r_e'' \leqq 2.26 \times 10^{-8}$ cm.

14. Spectrum of strontium hydride. WILLIAM W. WATSON, *Yale University*, AND W. R. FREDRICKSON, *Syracuse University.*—A metallic strontium arc in a hydrogen atmosphere yields three groups of bands in the near infrared with main heads at 7020A, 7347A, and 7508A. Analysis shows that the latter two constitute a $^2\Pi \rightarrow {}^2\Sigma$ system with only the (0,0) and (1,1) bands, while the first group represents a transition from a higher $^2\Sigma$ to the same ground $^2\Sigma$ level. Analysis of the (0,0) bands shows that the $^2\Pi$, $^2\Sigma$ band is similar to that of BaH, the constants being $A=327$, $B_0''=3.608$, $D_0''-2.63\times10^{-5}$, $B_{0,+\frac{1}{2}}^{*}=3.6727$, $p_0=-4.50$, and $q_0=-0.20$, with all figures subject to slight correction. The very large negative p_0 and q_0 indicate interaction with the near higher-lying $^2\Sigma$ level, and the corresponding large doubling of this level is exhibited in the structure of the 7020A band. This is much the largest doubling yet found in a $^2\Sigma$ level. The relative positions of the $^2\Pi$ and $^2\Sigma$ levels in CaH, SrH, and BaH and the atomic levels of Ca, Sr, and Ba suggest $\cdots d\sigma$ for the upper $^2\Sigma$ level.

15. Spectrum of barium hydride. W. R. FREDRICKSON, *Syracuse University*, AND WILLIAM W. WATSON, *Yale University.*—High dispersion spectrograms have been obtained of a BaH band system in the region 6925–6380A, the source being a metallic barium arc in a hydrogen atmosphere. The (0,0), (1,1), and (2,2) bands only are present. Analysis of the (0,0) band shows the system to be the expected $^2\Pi \rightarrow {}^2\Sigma$ case a type with twelve branches in each band. The Λ-type doubling is large in the $^2\Pi_{1/2}$ state, but small and of opposite sign in the $^2\Pi_{1\frac{1}{2}}$ state, giving $p_0=+0.85$ and $q_0=+0.0067$. The spin doubling is regular and gives $\gamma_0=+0.186$. Evaluation of the molecular constants from the $2\Delta F$ term differences gives $B_0''=3.404$, $D_0''=-9.61\times10^{-5}$; $B_{0,}'_{+\frac{1}{2}}=3.4468$, $D_{0,}'_{+\frac{1}{2}}=-1.13\times10^{-4}$; $B_{0,}'_{-\frac{1}{2}}=3.5156$, $D_{0,}'_{-\frac{1}{2}}=-1.20\times10^{-4}$. The separation of the two $^2\Pi$ sublevels, calculated in the usual way, yields $A=462$, as compared with $A=832$ for the ^3P levels of Ba. A large perturbation in one of the $^2\Pi_{1\frac{1}{2}d}$ levels, and the sign and magnitude of the p_0 and q_0, indicate another lower-lying excited level for BaH.

16. Heats of dissociation of Na_2 and K_2. R. E. NUSBAUM AND F. W. LOOMIS, *University of Illinois.*—The apparatus constructed to produce the magnetic rotation spectrum of Li_2 has now been employed to study those of Na_2 and K_2, and in particular to extend the spectra to the high v' levels of the excited state which are used in extrapolating towards dissociation. As with lithium, it is found that, near the limit, convergence takes place more rapidly than any simple polynomial extrapolation would indicate. For this reason Loomis' previous estimate of the heat of dissociation of sodium (1.0 ± 0.1 volts) and Crane and Christy's estimate for potassium (0.81 volt) were too high. The present measurements extend much further, coming within 0.03 volt of the estimated dissociation in the case of sodium and within 0.02 volt in the case of potassium. The heats of dissociation measured from the zero level of the normal state are, for sodium 0.76 ± 0.02 volt, for potassium 0.51 ± 0.02 volt. The value for sodium agrees closely with the best evidence from chemical data. That for potassium is in accord with the fact that density measurements of potassium vapor do not show a measureable amount of molecules.

17. Absolute value of transition probabilities in band spectra. R. LADENBURG, S. LEVY AND G. WOLFSOHN, *Kaiser-Wilhem-Institut f. Physik. Chemie, Berlin-Dahlem.*—By measuring anomalous dispersion near many lines of the red Li_2 bands we have determined the number of corresponding oscillators of the rotation lines. Calculating approximately the number of molecules in the rotational levels we find f-values of about 1/30–1/100 and transition probabilities (A-values of Einstein) of about 3×10^6. On the other hand we get no effect on the dispersion near the Schumann band lines of oxygen (*ca.* 1900A) at atmospheric pressure as measured with a fluorite interferometer. The transition probabilities of these lines are therefore relatively small (smaller than 10^3). The absolute determination of the dispersion over the region from the visible to 1900A shows that the main absorption band of oxygen with high transition probabilities lies in the region of 900A, as one would expect from the spectra of oxygen atoms and molecules.

18. A new criterion for predissociation. JOSEPH KAPLAN, *University of California at Los Angeles.*—From time to time the writer has reported some striking deviations from the intensity distributions predicted by the Franck-Condon principle. This phenomenon has been convincingly shown in the experiments of Lord Rayleigh and others on the afterglow of nitrogen in rare gases and also in the present writer's experiments on the emission spectra of nitrogen-oxygen mixtures. An explanation of this phenomenon is of considerable importance because it provides an interpretation of the striking role of rare gases in many experiments on the excitation of molecular and atomic spectra. It is shown that the effect can be interpreted as a criterion for predissociation, which is especially valuable in cases in which the probability of predissociation is not high enough to quench the emission bands completely, or to produce diffuseness in the rotational structure of the absorption bands. Experiments have been performed which show that predissociation is sensitive to excitation conditions. As a result of these experiments an explanation is obtained for certain astrophysical spectra in which the deviations from the predictions of the Franck-Condon principle are so large as to make the identification of some of the bands difficult.

19. The dissociation of nitrous oxide by light, and the electronic levels of O_3, N_2O and NO_2. OLIVER R. WULF AND EUGENE H. MELVIN, *Bureau of Chemistry and Soils, Washington, D. C.*—Nitrous oxide in long paths has shown no absorption over the region 10,500A to about 2000A where the absorption previously observed by Leifson (Astrophys. J. **63,** 73 (1926)) occurs. In the present work this has been observed to as long wave-lengths as 2300A. The absorption of this radiation leads to the appearance of the gamma bands of NO in absorption in the gas, and it is shown that the elementary act accompanying the absorption of this radiation is very probably the dissociation of N_2O into NO and N. Certain rather striking similarities are pointed out between the electronic levels of O_2 and O_3, and with this in mind, the electronic levels of N_2O and NO_2 are discussed.

20. The enhancement of the iodine absorption spectrum by the admixture of oxygen. F. W. LOOMIS AND H. Q. FULLER, *University of Illinois.*—When oxygen at atmospheric pressure, or even a few centimeters, is added to a tube containing iodine, many of the iodine absorption bands are greatly enhanced. The effect is under certain circumstances so pronounced that a

considerable change of color of the iodine is apparent. The enhancement is appreciable only for bands with $v'>12$ and begins at about this number in each of the progressions $v''=0, 1, 2$. It reaches a maximum at roughly $v'=25$ and thereafter decreases. The shape of this curve is very similar to that which Turner found for the quenching of iodine fluorescence by a magnetic field, and it is believed that the explanation of the effect is as follows: The oxygen, possibly by the magnetic fields of its $^3\Sigma$ molecules, relaxes the selection principle and allows the excited iodine molecules with $v'>12$ to predissociate. This shortens the lives of such molecular states and correspondingly broadens the absorption lines leading to them. The effect of broadening a very narrow absorption line, at the center of which nearly 100 percent of the light is being absorbed, is to increase the total amount of light absorbed. It is believed that this increase of absorption due to broadening offers a convenient means of locating and studying such induced predissociation effects. This phenomenon affords an explanation of Ramsauer's apparent observation that admixture of oxygen not only quenched iodine fluorescence, but that it weakened the various lines of a fluorescence series unequally. Actually the effect was due to reabsorption of the fluorescence lines while getting out of the iodine, this reabsorption being irregular along a fluorescence series, and being greater when oxygen was present.

SATURDAY MORNING AT 10:30 O'CLOCK

Room 32-Ryerson

21. Duration of afterglow in nitrogen. CHAS. T. KNIPP, *University of Illinois.*—A 22-liter Pyrex flask was prepared with a stem about 2 meters long and about 70 mm diameter. On April 10, 1930, it was pumped out to free it of moisture, and then without further drying or outgassing it was primed with tank nitrogen and sealed off at a pressure which gave the best electrodeless discharge. The exciting coil was permanently wound round the stem about 20 cm from the bulb and consisted of 7 turns of heavy lamp cord (No. 10) taken double. The flask with its stem was energized by damped oscillations from a motor-generator high-voltage high-frequency set. The bulb thus prepared has been under observation over an extended length of time, and has been flashed (duration about 0.1 sec.) but *three times since* the initial flash, resulting in the following data:

Date	Total interval	Duration of afterglow
April 10, 1930	0 days	35 min
Aug. 12, 1930	122 "	110 "
Mch. 4, 1931	324 "	187 "
Oct. 18, 1931	553 "	165 "

Apparently the duration of the afterglow reached a maximum in about a year. The observations are to be continued.

22. The Paschen-Back effect of hyperfine structure, I. Thallium II and thallium III. J. B. GREEN, *Ohio State University,* AND JOHN WULFF, *Massachusetts Institute of Technology.*—The Zeeman effect of thallium spark lines has been studied at full strengths of 14,700, 32,500, and 43,350 gauss with the 21-foot concave grating and large Weiss magnet of the University of Tübingen. In particular, λλ 3092, 2531, 2298 and 5950 of Tl II and 4110 of Tl III show exceptionally good agreement with Goudsmit and Bacher's theory of the Paschen-Back effect of hyperfine structure. λ3092 is especially suitable as a test of the theory since it is the simplest example of this effect, being a transition from $j=1$ to $j=0$ and involving a nuclear moment $i=1/2$, the smallest value yielding a hyperfine structure.

23. The Paschen-Back effect of hyperfine structure, II. Bismuth II and bismuth III. JOHN WULFF, *Massachusetts Institute of Technology,* AND J. B. GREEN, *Ohio State University.*—As a continuation of the work on the spark lines of thallium, the spark lines of bismuth were chosen. The Zeeman patterns of these lines are much more complicated, since the nuclear moment of bismuth is 9/2. In particular, the lines λλ5719 of Bi II and 4561 and 3695 of Bi III were investigated because of the rather large hyperfine structures involved in the transitions, and the sharpness of their magnetic patterns. An excellent agreement between theory and experiment was noted.

24. The polarization of mercury resonance radiation. L. LARRICK AND N. P. HEYDENBURG, *State University of Iowa.*—The polarization of the line λ2537A of mercury in resonance radiation is calculated on the assumption that isotopes 199 and 201 have nuclear moments of 1/2 and 3/2 respectively, while the even isotopes 198, 200, 202, and 204 have zero nuclear moment as Schüler and Keyston have suggested (Naturwiss. **31,** 676 (1931)). With "broad line" and "narrow line" sources respectively, resonance radiation excited by light polarized with the electric vector parallel to the magnetic field should be 85 percent and 89 percent polarized, in fair agreement with the observations of Olson 79 to 86 percent (Phys. Rev. **32,** 443 (1928)), and von Keussler, 79.5 percent (Phys. Zeits. **27,** 313 (1926)). Relative transition probabilities within a hyperfine multiplett are calculated on the assumption of *LJS* type coupling between *J*, *F* and *I*.

25. Polarization of cadmium resonance radiation. A. ELLETT AND L. LARRICK, *University of Iowa.*—The cadium resonance lines λλ2288 and 3261A excited by unpolarized radiation in a magnetic field parallel to the exciting light beam are found to be 76 percent and 85–86 percent polarized respectively. From spectroscopic evidence Schüler has assigned nuclear moments of 0 and 3/2 to the even and odd isotopes of Cd. Separations in 2288 are small compared to Doppler breadth, while in 3261 the strong component of the 3/2 isotope pattern merges with the 0 isotope line. If we suppose that the introduction of spin does not change the net transition probabilities between the gross levels concerned these polarization values both yield 2.5 for the ratio of abundance of even and odd isotopes. A recent calculation of C. D. Mitchell leads to other results, but is based on the apparently incompatible assumptions that intensities in the source are proportional to isotope abundance but in absorption are determined by assigning equal weights to Zeeman levels making absorption by the spin isotope twice that by the non-spin isotope for equal abundance and uniform spectral distribution, conflicting with Kirchhoff's law.

26. A note on the origin of continuous cometary spectra. WILLI M. COHN, *A. D. Little, Inc. Cambridge, Mass.*—Different theories concerning the origin of the continuous spectra of comets are discussed. The "solar type spectrum" with a maximum at 4700A may be explained by the reflection from particles contained in the comets large in comparison to the wave-lengths of the incident light. Laboratory experiments show that continuous spectra may be produced by bombardment of ions of different materials with electrons in high vacuum. A theory is developed which assumes that electrons are emitted constantly from the sun. These electrons will give rise to the "violet type spectrum" (maximum at 4000A) and—in the tail at a great distance from the head—to the solar type continuous spectrum observed in comets. The polarization phenomena of the light emitted by comets are explained by the new theory. Continuous spectra of straight and curved tails are expected to differ in the shift of the maximum with growing distance from the head. Band and line spectra observed in comets are assumed to be mainly excited by electrons emitted constantly from the sun.

27. Inner vibrations in molecules from the Raman effect. WILLIAM D. HARKINS AND HAROLD E. BOWERS, *George Herbert Jones Laboratory, University of Chicago.*—The Raman frequency characteristic of a carbon-halogen bond is found in normal compounds to be independent of the length of the chain between two and five carbon atoms. This indicates that the characteristic frequency is related to an inner and not to an outer vibration. A comparison of the values with those for the methyl compounds seems to indicate that the group which vibrates is the $-CH_2$ group adjacent to the halogen atom. However this is affected by the constraints from and the vibrations of the other parts of the molecule. A not too distant branching of the chain reduces the frequency by about five percent. The force constants are calculated as 3.0 for the chlorice, 2.6 for the bromide, and 2.2 for the iodide, in 10^5 dynes per cm, which is much lower than the value of about 5.0 found for the single bonds C.C, C.O, and C.N.

SATURDAY MORNING AT 10:30 O'CLOCK

Room 133-Eckhart

28. Effect of the target on breakdown in cold emission. WILLARD H. BENNETT, *Ohio State University.*—A tube was used in which cold emission was drawn from a fine point to a plane. By means of a magnetic field, the electrons could be prevented from striking the anode in the vicinity of the cathode but the electrons could be forced to strike the anode in parts of the tube well removed from the cathode. After breakdown had been produced, by using unoutgassed electrodes, and the current had been made steady by reducing the electric field slightly, fresh ruptures of the cathode occurred whenever the magnetic field was changed to a value not previously used. The observations can be explained on the basis that breakdown is due to the rupture of the cathode surface by a highly concentrated stream of positive ions which is produced by an initial small electron emission from a point on the cathode near where breakdown occurs, but not directly at it.

29. A new method of determining thermionic work function by photoelectric cell. ROSCOE E. HARRIS, *Lake Forest College.*—A method of determining thermionic work function has been developed which uses a photoelectric cell to identify sameness of temperature. Change of filament wattage upon emission was measured with potentiometer accuracy while the filament was maintained at a constant brightness temperature as indicated by the photoelectric cell. Simultaneous data were obtained for determining the work function from saturation currents, and compared with this latent heat method. The sensitivity was such that one mil change in emission current caused up to 50 mm deflection upon a galvanometer. This method gave consistent values about 3 volts higher than those obtained by saturation current method, the latter values being similar to those usually accepted. Calculation of the resistance of the filament indicates an increase of resistance upon emission without change in temperature. The assumption of constant resistance may account for different values obtained by others with the latent heat method. Recent statistical theories indicate that the usually accepted values of the work function may be too small. The working equation used in this method seems to be independent of the statistical theory employed.

30. The emission of positive ions from metals. H. B. WAHLIN, *University of Wisconsin.*—When a tungsten wire containing uranium dioxide was heated to a temperature of about 1800° C three types of ions were observed by a magnetic deflection method, Ur^+, W^+, and an ion of mass 254 ± 2. This is probably UrO^+. Assuming this to be the case it seems more probable that an ion of mass 247 ± 2, which was observed when thoriated tungsten was heated and which has been reported earlier, is ThO^+. An investigation of the positive ions from Cu and Ag has shown that at a temperature just below and persisting above the melting point, ions of the metals themselves are emitted. This characteristic ion current is small compared with that due to alkaline impurities.

31. Spurious contact potentials and "trapped" electrons. W. B. NOTTINGHAM, *Massachusetts Institute of Technology.*—The contact potential between a thoriated filament and a nickel collector has been observed to depend on the "history" of the current flow to the collector. This experimental result can be explained by assuming a potential barrier near the nickel surface following the mirror image law from infinity to within about 3×10^{-7} cm, joining a potential function with a minimum and a maximum following the Fowler-Nordheim theories of composite surfaces, an experimental test of which was reported at the Schenectady Meeting. Electrons caught in the potential valley are assumed to run over the surface as a two dimensional gas producing a change (Δv) in the effective contact potential of approximately $\Delta v = 4\pi ned$ (n = number of electrons per cm²; d = width of potential hill separating electrons from metal). The valley is "populated" by allowing a large current to flow to the collector for a time assuming that a small number of electrons fall into the valley. Experimentally determined "mean lives" of electrons in the valley are $t_1 = 5{,}000$ sec. and $t_2 = 456$ sec. The formula,

$$t = 1/f \exp\left\{\frac{4\pi}{h} \int (2m(V - W))^{1/2} dx\right\},$$

where $(V-W)$ is the difference between the electron energy and the potential function depending on x, and f is the number of approaches to the potential hill made by an electron per sec., can be used to calculate t for any particular potential barrier. It has been found possible to construct a potential barrier of "atomic dimensions" for which the observed mean lives are the appropriate ones for the lowest and the next lowest "quantized" states in the valley. This theory explains certain changes in the current flowing in FP-54 pliotrons and many other results in experiments involving contact potentials.

32. Electric oscillations in ionized gases—some remarks on their present theories. J. KUNZ, *University of Illinois.*—The frequency of oscillations in ionized gases is given by

$$\cdots \omega^2 = 4\pi(e^2/m)N, \tag{1}$$

ω being the frequency per 2π seconds, N the number of electrons per cm^3, e the charge, and m the mass of the electron. The theory of Sir J. J. Thomson and I. Langmuir and L. Tonks can be applied also to a gas containing mostly positive ions and finally to a gas containing positive and negative ions. Let E be the electric force acting in the gas, $E=E_0 \cos \omega t$, i be the current, $i=Neu$, where u is the velocity of the electrons, $u=[Ee/(\omega m)] \sin \omega t$, then $i=N(E_0e^2/\omega m) \sin \omega t = I \sin \omega t$, where the amplitude of the alternating current

$$I = NE_0e^2/(\omega m). \tag{2}$$

But from (1) and (2), $Ne^2/m=I\omega/E_0=\omega^2/4\pi$, or

$$\omega = 4\pi I/E_0. \tag{3}$$

For a constant electric force E_0 we see that the frequency is proportional to the alternating current I. We next assume that the density ρ of negative ionization over a distance l shall be constant. Then we can write, $\omega^2=4\pi\rho e/m$, and $E=-4\pi\rho\omega x=-dV/dx$ and the potential difference $V=2\pi\rho l^2$, or $\rho=V/2\pi l^2$ and $\omega^2=(2eV)/(ml^2)=(2\pi c/\lambda)^2$, hence

$$\lambda = 2\pi cl(m/2e)^{1/2}V^{-1/2}. \tag{4}$$

We compare this last result with the original wave-length determined by Barkhausen and Kurz for the short oscillations in three electrode tubes. They found that the oscillations could be explained by the assumption that individual electrons oscillate between the filament and the grid or the plate and that the corresponding wave-length λ is equal to

$$\lambda = 2cl(m/2e)^{1/2}V^{-1/2}. \tag{5}$$

Their formula differs from (4) by a factor π. In this paper, I hope to offer further considerations regarding the coupling of these oscillations with external circuits.

33. Electron oscillations in thermionic tubes. J. T. TYKOCINER AND A. E. ABEL, *University of Illinois.*—The special type of Barkhausen oscillations, which show a liinear relation between the wave-length λ and the length L_e of the external circuit, was investigated in regard to the mechanism of oscillations. It was found that the electron cloud may be considered as an oscillating system equivalent to an internal circuit L_i of half a wave in length and coupled electrostatically with the external circuit. If the total length $L_t=L_i+L_e+L_c$, where L_c represents a correction due to the influence of electrodes, is plotted against λ, a group of linear segments is obtained all directed towards the origin of the coordinate system. Each of the segments belongs to a zone of oscillations separated by a zone of inactivity or of feeble oscillations of a different type. Data on seven zones thus investigated verify the theory. The slope of the segments for a single oscillating tube is given by the expression $\cot \alpha=L_t/\lambda=(n\lambda+\lambda)/\lambda=n+1$, where $n=1, 2, 3 \cdots$ is the order of the sequent zones. Experimental data obtained with a single UX-852 oscillator tube agree closely with this formula. Similarly results of measurements made with an oscillator consisting of two such tubes agree with the theoretical values calculated from $\cot \alpha=(n\lambda+3/2\lambda)/\lambda=n+3/2$. In the first case the experimental values for $\cot \alpha$ were 2, 3, 4, 5, respectively, while in the second case they were 2.5, 3.54, 4.52, 5.6 ect. In both cases the values increase by unity for each subsequent zone.

34. A thermionic frequency doubler. C. K. STEDMAN, *Purdue University.*—The output voltage of a thermionic tube operated over a suitable restricted range of grid voltages may be

represented approximately by the parabola $e_p = b_0 + b_1 e_g + b_2 e_g^2$. By adding in opposite phase the output of another tube, operated on the straight line portion of its curve, we may balance out entirely the term $b_1 e_g$, so that the characteristic of the combination of tubes is $e_c = b_0 + b_2 e_g^2$. The system will then operate as a frequency doubler, for the output is proportional to e_g^2 alone. With a 201A tube an output of 0.175 volts of frequency $2f$ is obtained from an input of 1.0 volts of frequency f. It is found that when the characteristic of the system is plotted, the curve is never a symmetrical parabola $e_c = b_0 + b_2 e_g^2$ over a very wide range of grid voltages, because the coefficient of the cube term in the equation of the tube characteristic is not negligibly small, and the equation must be written $e_c = b_0 + b_2 e_g^2 + b_3 e_g^3$. It is shown how the coefficient b_3 may be determined by measuring the dissymmetry of the curve. Since b_2 governs the amount of desired second harmonic, and b_3 the amount of third harmonic distortion in the output, a good figure of merit for the frequency doubler is b_2/b_3. With the tubes tested this quantity varied from 45.0 to 6.0. In the case of the 201A tube mentioned above $b_2 = 0.35$ and $b_3 = 0.0085$.

SATURDAY AFTERNOON AT 2 O'CLOCK

Room 32-Ryerson

35. Automatic voltage control by means of a photoelectric cell. H. T. CLARK AND W. KOHLHAGEN, *Purdue University.*—The method described by Lark-Horovitz and Sherman some time ago (Phys. Rev. **32,** 328 (1928)) for regulation of voltage by the use of a photoelectric cell in connection with a mechanical device has been modified by using electrical control throughout. The photoelectric current is amplified by two stages of screen grid amplification directly coupled and a last power stage consisting of four 250 tubes in parallel. The plate current is used as a variable shunt across an external resistance in series with the field of a 500 cycle generator; and the potential drop across this resistance furnishes the plate voltage for the power tubes. The maximum plate current, using 175 volts drop across the power tubes, is about 360 milliamperes—more than one third of the field current required for normal voltage output. The sensitivity reached is about 200 milliamperes for a change in light of 0.35 lumens.

36. A new Wilson apparatus for the photography of alpha and beta-ray tracks. DAVID M. GANS, WILLIAM D. HARKINS, AND D. A. WALLACE, *University of Chicago, Dept. of Chemistry.*—A large Wilson ionization chamber, 17 cm in diameter, has been constructed in this laboratory for operation at gas pressures from 4 cm of mercury to several atmospheres, in order to show the disintegration and synthesis of atomic nuclei and to give greater accuracy in the study of the quantum relations of the nucleus. In the design are included ideas developed by Wilson, Shimizu, Harkins and Ryan, Petrova, Hippel, and others. The action is entirely mechanical and periodic, and the principal feature is the fact that every important operation can be timed with considerable accuracy by a simple mechanism. The shutter which admits alpha-rays lies entirely within the chamber, and is operated accurately by two electromagnets that lie outside. This avoids surges in the gas, which have been the cause of considerable inaccuracy in earlier forms of apparatus that operated continuously. A pressure of one-half atmosphere is used to give greater accuracy in the measurement of angles than can be obtained at higher pressures. Still lower pressures may be used as easily, but lower the number of inelastic nuclear collisions obtained.

37. On the structure of vitreous oxides. W. H. ZACHARIASEN, *University of Chicago.*—Of all the different oxides X_mO_n only a limited number have been prepared in the vitreous form. This fact can be explained on the basis of the hypothesis that the atomic arrangement in vitreous solids is characterized by extended three-dimensional networks that differ from the crystalline networks by the absence of periodicity and symmetry. We consider the oxides to be built up of oxygen polyhedra which are formed around the atoms X. The periodicity and symmetry of crystals arise from the fact that the oxygen polyhedra share corners with each other in such a way that the polyhedra assume definite relative orientations. The formation of a vitreous solid thus will depend upon the nature of the polyhedra and the way in which they link together. In the case of individual oxides the conditions for the formation of glass can be expressed in the following simple rules: (1) Two polyhedra have not more than one corner in

common, (2) An oxygen atom is linked to not more than two atoms X, (3) The number of corners in each polyhedron is small, probably less than six, (4) At least 3 corners in each polyhedron are shared with other polyhedra. Only the following oxides satisfy these requirements: B_2O_3, SiO_2, GeO_2, P_2O_5, As_2O_5. Some doubtful ones are P_2O_3, As_2O_3, V_2O_5, Sb_2O_5, Cb_2O_5, Ta_2O_5, Sb_2O_3. Vitreous modifications have been observed for B_2O_3, SiO_2, GeO_2, P_2O_5, As_2O_5, As_2O_3, in excellent agreement with the derivation. Many properties of glasses can be accounted for on the basis of the hypothesis proposed. Investigations on the composition and properties of general types of glasses are in progress.

38. On the detection of inhomogeneities in the magnetization of iron. FRANCIS BITTER, *Westinghouse Research Laboratory, East Pittsburgh, Pa.*—A method has been developed for detecting inhomogeneities in the magnetization of ferromagnetic materials. This consists of allowing small permanently magnetized particles of Fe_2O_3 (approximately 10^{-4} cm in diameter) suspended in alcohol to settle gently on a magnetized surface. At a certain critical magnetization the suspension settles in parallel straight lines whose direction varies from grain to grain. These lines are usually more or less perpendicular to the direction of magnetization. Within a single grain the spacing is regular and usually in the neighborhood of 0.1 mm. The lines do not turn when the direction of the field is changed, but gradually disappear and new sets of lines appear. It is improbable that they have anything to do with slip planes, first because they are not always perfectly straight, and secondly because they have been observed on the surface of a melted sample that was never subjected to any mechanical treatment whatever. For large magnetizations the lines degenerate into irregular spots elongated at right angles to the direction of magnetization and do not stop at grain boundaries. It is suggested that the observed patterns are due to a periodicity inherent in the nature of magnetization.

39. The Hall effect on induced currents in circular disks of bismuth and antimony. CARL A. BECK, *Northwestern University.*—Corbino (Phys. Zeits. **22,** 561 (1911)) found this induced effect in bismuth. According to his theory, the quantity of electricity which flows radially is $-(1/8\pi R)c_H SH^2$, where R is the resistance of the galvanometer circuit, and c corresponds to the final field, H. Thus the equivalent change of flux in this circuit is $N=(-c_H SH^2)/8\pi$. On the other hand, K. K. Smith deduced the formula, $N=-S/4\pi\int_0^H cHdH$. These expressions agree only if the coefficient c is independent of H. Experiments on bismuth show that the value of the coefficient in the first formula is always greater than that derived from the second. For the coefficient decreases as the field increases, and the value calculated from the first formula corresponds not to the final field but rather to a weaker field. By using rectangular plates cut from the circular disks, one finds, with steady currents and steady magnetic fields, that the ratio of Hall coefficient to resistivity agrees more nearly with the coefficient derived from the second formula than with that from the first. In antimony the induced effect has been found. It is small and opposite in sign to that in bismuth. The coefficient decreases only slightly as the field increases.

40. Supercooling liquid copper. J. J. HOPFIELD, *Chicago, Ill.*—A striking example of supercooling is provided by liquid copper. I know of no other case where this phenomenon is shown by the change in brightness of a body. The apparatus necessary is a glass rod (preferably Pyrex) with a globule of copper fused into it, and a blast lamp using oxygen. The demonstration is as follows: the glass containing the metal is heated until the copper is melted and then removed from the flame. If the copper sphere has a diameter of 2 mm or more it cools about 40°C below its melting point, and then flashes bright remaining so while solidification is taking place. Under suitable conditions this supercooling of copper may furnish a handy reference point in calibrating optical pyrometers. After the initial flash there may be a weak second flash, probably due to copper oxide. The supercooling is greater for smaller droplets, and the flashing time is shorter. Supercooling in copper does not depend primarily on pressure for it occurs even at atmospheric pressure. It depends upon the purity of copper. Copper alloyed with about ten per cent of gold or silver does not show it. Under the conditions studied neither gold nor silver shows the effect.

41. Thermal expansion of electrolytic chromium. PETER HIDNERT, *Bureau of Standards.*—The linear thermal expansion of a 300 mm tube of electrolytic chromium prepared here by

G. E. Renfro was investigated between 20 and 500°C. The composition determined by R. M. Fowler was as follows: Chromium 99.3, silicon 0.002, iron 0.002 percent, manganese, lead and copper not detected. Chromium produced here under similar conditions was found by H. C. Vacher to contain about 0.1 percent hydrogen. Further tests will be required to identify the remaining 0.6 percent in this material. During the first expansion test the chromium tube contracted considerably on heating to 500°C due to evolution of hydrogen. After cooling to 20°C, the tube was 1.1 percent shorter than before heating. The following coefficients of expansion were derived from the observations on heating in the second and third tests.

Temperature range (°C)	Average coefficients of expansion per degree centigrade	
	Test 2	Test 3
	$\times 10^{-6}$	$\times 10^{-6}$
20 to 60	6.2	5.9
20 to 100	6.8	6.7
20 to 200	7.5	7.5
20 to 300	8.1	8.1
20 to 400	8.5	8.6
20 to 500	8.6	8.8

E. L. Peffer found that the density of a duplicate tube of electrolytic chromium (before heating) was 6.93 g/cm³ at 25°C.

Paper No. 41 will be read by title.

SATURDAY AFTERNOON AT 2 O'CLOCK
Room 133-Eckhart

42. A gravitational explanation of the spectral shift of light from very distant stars. HERBERT J. BRENNEN, *Northwestern University.*—In recent years, it has been found that, for light from very distant stars, the spectral shift towards longer wave-lengths is greater, the greater the distance of the star from us. It has been assumed that this shift is due to a Doppler effect but this leaves unanswered the question why all of the very distant stars should be receding from us. However, by assuming nebulae of radii of hundreds of thousands of light years and having densities of the order of 10^{-21} gram per cubic centimeter, it is shown that the spectral shift can easily be explained as merely a gravitational effect and, moreover, equations are derived which show, as a first approximation, that the spectral shift is proportional to the distance of the star.

43. The Beryllium molecule. W. H. FURRY AND J. H. BARTLETT, JR., *University of Illinois.*—The existence of a stable diatomic beryllium molecule has not yet been inferred either from band spectra or on theoretical grounds. By an application of the Heitler-London method, which gave good results for Li_2, the writers have previously shown that two normal beryllium atoms repel each other (Phys. Rev. **38,** 1615 (1931)). This work has been extended to the case in which a normal beryllium atom interacts with a beryllium atom having the configuration $2s2p$ (^1P and ^3P states). The K-shells have been neglected and a much more general notation than that hitherto used has been adopted. Even then however the calculation becomes so complicated that its extension to the problem of B_2, where six electrons interact, does not seem practical at the present time. It is found that of the eight molecular states two may give rise to a stable molecule. The lower is a $^1\Sigma$, the other a $^1\Pi$. The heat of dissociation for the $^1\Sigma$ is of the order of two volts.

44. Corpuscular description of electron diffraction phenomena. R. M. LANGER, *University of Minnesota.*—It is generally not sufficiently emphasized that the particle interpretation of experiments on diffraction of electron and atom beams is simpler and more straight forward than the customary wave interpretation. The argument originally given by Duane for x-ray reflection applies equally well for any particles, and the modern conception of a solid justifies

the assumption of Duane that momentum can be transferred only in quanta. With this assumption the application of the conservation of energy and momentum leads directly to the Bragg reflection formulae. No wave properties of the impinging beams are relevant in any of the experiments thus far performed. This description has the advantage of clarity over the wave formulation especially when the explanations of surface effects, ordinary ruled grating reflections and half order reflections are concerned. The patterns due to single molecules can also be treated without relying on any coherence or interference of the scattered electrons. Losses of small amounts of energy on reflection should occur with considerable probability but the question of their influence on the diffraction pattern has not yet been sufficiently studied.

45. A further generalization in the kinetic interpretation of the Kelvin relations. E. A. UEHLING, *University of Michigan.* (*Introduced by G. E. Uhlenbeck.*)—The derivation of the Kelvin relations for the reversible heat development and the thermoelectric force in anisotropic crystals is shown to depend only on the assumption of the principle of detailed balancing. Previous treatments have been less general. The work of Nordheim is valid only for isotropic materials, and that of Ehrenfest and Rutgers depends on the assumption of elastic collisions between the electrons and the atoms of the metal. These restrictions are shown to be unnecessary. These authors also use special methods of reducing the integral equation which determines the distribution function. In the general case these methods are impossible and prove to be unnecessary. Because of the principle of detailed balancing, the integral equation has essentially a symmetric kernel. By using the formal Fredhohn solution one can derive the electric and heat current equations and prove certain reciprocal relations, from which the Kelvin equations follow. These conclusions may be considered as a substantiation in a special case of the very general considerations of Onsager.

46. The impuls-energy tensor of the Dirac equations. O. LAPORTE AND G. E. UHLENBECK, *University of Michigan.*—Extending our considerations on the applications of the spinor analysis to Dirac equations (Phys. Rev. **37,** 1380 (1931)), we have translated the results of Tetrode on the impuls-energy tensor into the spinor language. Starting from the second order Dirac equations, one can derive

$$f^i = \partial T^{i\alpha}/\partial x^\alpha$$

when f^i is the four-force, and T^{ik} a tensor quadratic in the ψ and their derivatives. T^{ik} can now be split up in the symmetric S^{ik} and antisymmetric part A^{ik}, and for the latter one can prove:

$$A_{lm}{}^* = (\partial k_m/\partial x^e) - (\partial k_l - \partial x)^m$$

when $A_{lm}{}^*$ is the dual of A^{ik} and k_m the four vector, with components quadratic in ψ introduced by us (l.c. p. 1396). Thus we may write:

$$f^i = \partial S^{i\alpha}/\partial x^\alpha$$

when now S^{ik} is a symmetric tensor, but with the diagonal sum not zero. The application of the spinor analysis has the advantage, besides giving the equations in an automatically covariant form, that it is very easy to decompose any tensor T^{ik} into its irreducible parts.

47. A note on the uncertainty principle. E. L. HILL, *University of Minnesota.*—Frenkel has suggested that one can interpret the uncertainty principle for one electron by saying that the magnitude of the momentum has a definite (i.e. the *classical*) value, but there is an ambiguity in the direction of motion. It has been found possible to rewrite the wave equation for motion in one-dimension in such a way as to show that this interpretation seems in agreement with the wave mechanics (when $E \geq V$). The method lies in resolving the wave function into beams, one moving to the right and one to the left, each having the classical velocity. The electron then moves with the classical velocity but it has a chance of being reflected at every point, thereby changing its direction of motion. The average drift of electrons is measured by the current which is the (vector) sum of the currents for the two beams, written in the classical form current = density × velocity. Application of the momentum operator yields the classical value for the magnitude of the momentum, the sign being opposite for the two beams.

48. Electricity as a natural element of Riemannian geometry. CORNELIUS LANCZOS. (*Introduced by K. Lark-Horovitz, Purdue University.*)—The gravitational equations $R_{ik} = 0$, excluding

singularities, give only a Euclidian geometry. For a more generalized geometry, according to the differential character of Riemann's geometry we have to expect field equations for the fundamental quantity R_{ik}. We can prove generally that if these field equations can be deduced from a Hamiltonian principle the integration of the field equations leads to the appearance of a free vectorial function ϕ_i. The mathematical reason for this fact is that the curvature tensor R_{ik} has to obey the conservation law div $(R_{ik}-\frac{1}{2}Rg_{ik})=0$, besides the field equations. This additional condition gives a determination for the free vectorial function ϕ_i. If we select the Hamiltonian function by the natural idea of "guage-invariance," this vectorial function ϕ_i seems to correspond in all its properties to the electromagnetic vector potential. The conservation law is strictly the potential equation in a first approximation, and for the action of the field on a material particle we obtain in first approximation the Lorentz ponderomotive force. The antisymmetric tensor of the electromagnetic field-strengths appearing in this force law has otherwise no fundamental significance.

49. β disintegration. ARTHUR BRAMLEY, *Bartol Research Foundation.*—The electrons in the nucleus are supposed to be either firmly bound to an α-particle or free to move about the α-particles similar to the bound and free electrons in a metal. The free electrons are prevented from leaving the nucleus by a potential barrier of height C and width d at distance a from the center of the nucleus. The energy of the electron E is supposed to be small compared with C. In β-particle disintegration, an excited α-particle gives its energy ϵ to the electrons by internal absorption. The electrons are distributed in the nucleus according to the Bose-Einstein law, that the number of particles with energy E, $N(E)$ is

$$N(E)\alpha E \backsim \frac{E^2 dE}{e^{E/(A\epsilon)}-1}.$$

The probability $P(E)$ of an electron of energy E leaving the nucleus is (Fowler and Wilson, Proc. Roy. Soc. **A124**),

$$P(E) \backsim \frac{E^{3/2}}{c^2} e^{-2K(C(a+d)^2)^{1/2}}$$

so that the distribution of β-particles after leaving the nucleus is

$$L(E)dE \backsim \frac{E^{7/2}\cdot dE}{e^{E/(A\epsilon)}-1}.$$

The probability of a β-particle emission is

$$\int_0^\infty L(E)dE \backsim (A\epsilon)^{4.5}.$$

Thus the reciprocal of the mean life should vary as the 4.5 power of the energy of the excited α-particle.

The assumption has been made in the derivation that the rest energy $m_0c^2 < E$. It makes no appreciable difference with the available data whether the Bose-Einstein or Fermi-Dirac statistics is used.

50. On the physical nature of ponderomotive forces between living cells.—N. RASHEVSKY, *Westinghouse Elect. & Mfg. Co., East Pittsburgh.*—It has been observed, that isolated living cells sometimes exert on each other forces of attraction or repulsion. It was also suggested that these forces are due to the action of certain substances whose concentration is non-uniform around the cell. According to Rhumbler, if a substance lowers the surface tension of the cell, the cell tends to move in the direction of lower concentrations of the substance. In the present paper the problem is treated mathematically, from a more general point of view. An expression is derived for such forces, as would result on a small liquid drop, placed in a field of non-uniform concentration of a substance, which in general is assumed to be also soluble in the drop. This expression is composed of two terms, of which one represents the force, due to the influence of the dissolved substance on the surface tension of the drop. But the other term, which may even exceed the first, is independent on any surface phenomena, and represents a volume effect, due to the circumstance, that whenever the drop is brought from a region with one

concentration into that with another, the concentration of the substance inside the drop changes also, and this is accompanied by a change in the free energy of the system. Some consequences of the formulae are discussed.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program, to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for at any session in Room 133 Eckhart Hall.

51. Rotational analysis of the red K_2 bands. F. W. Loomis, *University of Illinois.*—The plates taken by Loomis and Wood to determine whether or not the nuclear spin of K_2^{39} is zero have been measured and the (1,0) (1,1) (0,1) and (0,2) bands of the red K_2 system have been analyzed. As expected, the system is found to belong to a $^1\Pi \leftarrow {}^1\Sigma$ transition. The most important rotational constants are as follows:

$$B_0'' = 0.05611 \qquad r_e'' = 3.91 \times 10^{-8} \qquad \alpha'' = 0.000219$$
$$B_0' = 0.04812 \qquad r_e' = 4.22 \times 10^{-8} \qquad \alpha' = 0.000235.$$

The relationships between the molecular constants show that all rotational levels, with both even and odd J, are present. Lines with odd J'' are stronger than neighboring lines with J'' even. Hence the conclusion of Loomis and Wood, that the nuclear spin of potassium is definitely not zero, is confirmed and it is concluded that the K^{39} nucleus obeys the Fermi-Dirac statistics.

52. Oscillations in corona discharges. J. T. Tykociner and W. A. Laning, Jr., *University of Illinois.*—In continuation of the investigation reported at the Washington meeting May 1, 1931 (Abs. 49, Phys. Rev. **37,** 1689 (1931)) an oscillographic study was made of oscillations in corona discharges produced by constant potentials within the range of 600–1500 volts, 5–150μa and 2–30 mm Hg pressure. The discharge appeared mostly in form of beads on a wire at negative potential within a cylindrical anode. When the potential was gradually increased regions of regular oscillations (sine waves) followed in succession the regions of irregular oscillations (complex wave forms). The latter occurred during a state of transition of the discharge from a single bead to a double or multiple number of beads. By evaluating the oscillograms the following correlations were found for the frequency, superimposed corona current, pressure and amplitude in the region of regular oscillations. At constant pressure the frequency (3000–15000) is proportional to the d.c. corona current. The amplitude is a linear function of frequency, a linear function of superimposed corona current and a complex function of the pressure. At constant superimposed corona current the frequency increases with pressure. The rate of change $\Delta f/\Delta p$ increases linearly with pressure. At pressures below 2 mm Hg oscillations set in when the wire is at positive potential. Details of the investigation will be published in a bulletin of the Eng. Exp. Station, University of Illinois.

Paper No. 52 will be read by title.

53. The method of least squares. Herbert J. Brennen, *Northwestern University.*—The ordinary method of least squares of finding the values of n of the $n+1$ coefficients (the $n+1$th coefficient being put equal to unity), of a linear equation in n variables, $x_1, x_2, \cdots, x_n$,

$$a_0 + a_1x_1 + a_2x_2 + \cdots + a_nx_n = 0 \qquad (1)$$

suffers from the fact that, in general, $n+1$ different solutions of the problem are obtained depending on which one of the $n+1$ coefficients is put equal to unity. Furthermore, the value of the sum of the squares of the so-called residuals is changed if the original equation is multiplied by a constant although the graph is unaltered; for this reason it difficult to compare the different solutions obtained. If, however, we put:

$$F \equiv \Sigma E_i^2 + \lambda^2(a_1^2 + a_2^2 + \cdots + a_n^2) = 0 \qquad (2)$$

where ΣE_i^2 is the sum of the squares of the residuals and λ^2 is an undetermined multiplier; and carry out the minimization with respect to all the coefficients before assigning the value of unity to any one. This procedure gives us $n+1$ linear homogeneous equations in the $n+1$ unknown coefficients; the vanishing of the determinant of these equations permits the calculation of the value of λ^2, the smallest (positive) value being chosen. Now we may equate to unity any coefficient we choose and solve any n of these equations for the other n coefficients. Furthermore, the value of λ^2 is unaltered when the original equation is multiplied by a constant.

54. Oriented molecules at the solid-liquid interface and the non-specific nature of ordinary adsorption. WILLIAM D. HARKINS, *George Herbert Jones Laboratory, University of Chicago.* —If a powder, whose grains have clean surfaces, is immersed in a liquid heat is evolved, about 1 calorie per gram for many fine powders. With titanic oxide the relative values with different liquids are (data of Harkins and Dahlstrom) water 1.00 (absolute value 1.15 calories per gram), butyric acid 0.77, ethyl acetate 0.70, butyl alcohol 0.67, acetone 0.58, carbon tetrachloride 0.47, and benzene 0.34. With other powders of the nature of stannic oxide, zinc oxide, silicon dioxide, and barium sulphate, the relative values are approximately the same, except in individual cases (as zinc oxide and an acid) in which it is known that a chemical reaction occurs. Thus the effect may be considered as due in general to non-specific or non-chemical forces. If an organic acid (or water) is added to benzene the heat of immersion of the powder rises rapidly until the heat evolved becomes almost as high as with the pure acid (or water) just as the monomolecular adsorbed film becomes tightly packed (Harkins and Gans). Thus when the amount of water present in the benzene is 0.03 percent the heat of immersion is increased by three times by this small quantity of water. Such monomolecular films produce very remarkable effects in connection with the settling of powders in liquids, often reducing the volume to one-fifth of that occupied by the suspension when the monomolecular film is not present. The great effect of polar groups in increasing the energy of immersion shows that the molecules at the interface are oriented with their polar groups toward the solid and the nonpolar groups toward the liquid.

55. Comparison of cosmic rays in the Alps and the Rocky Mountains. A. H. COMPTON, *University of Chicago.*